AEROGEL CHARACTERIZATION

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OUTLINE

- List of the silica aerogel tiles under test
- Measurements of optical transmittance
- Fit of transmittance data
- Transmission length evaluation
- Summary

TILES CHARACTERISTICS

Tile	n	t [cm]	Tile	n	t [cm]
1	1,03	2	18	1,005	2
2		2	19		2
3		2	20		2
4		2	21	1,03	2
5		2	22		2
6		1	23	1.02	2
7		1	24		2
8	1,04	2	25		2
9		2	26		2
10		2	27	1.02	2
11		2	28		2
12		2	29		2
13	1,05	2	30		2
14		2	31		2
15		2	32		2
16		2	33		2
17		2	34		2

Measurements performed on **22 silica aerogel tiles** at CERN in July-August 2022.

Tiles manufactured at Aerogel Factory Co., Ltd. and delivered in March 2021.

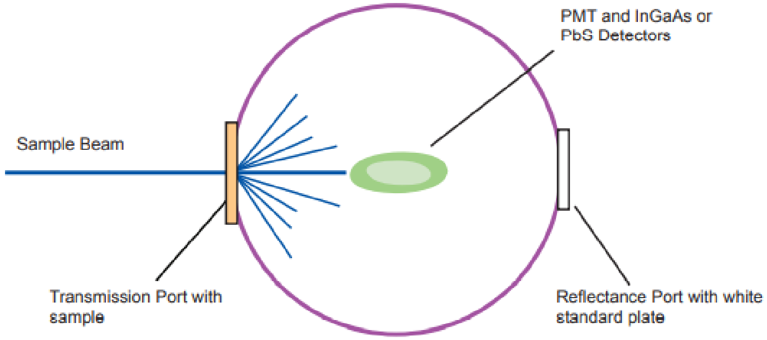
Tiles 6 and 7 manufactured by Matsushita Electric Works (Japan) were bought by INFN-Bari in 2000 as part of the HERMES collaboration.

Transmittance measurements on tiles with n = 1.02 are courtesy of the INFN-Ferrara group.

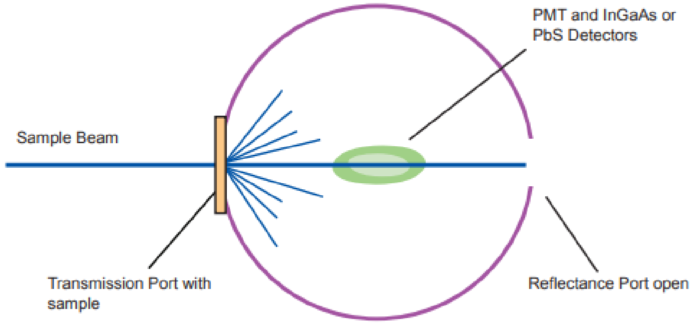
Tiles having **different refractive indices** have been characterized in terms of transmittance and tile thickness and shape.

TRANSMITTANCE MEASUREMENT

Perkin Elmer spectrometer: integrating sphere and two different light sources to cover the range 250 - 800 nm

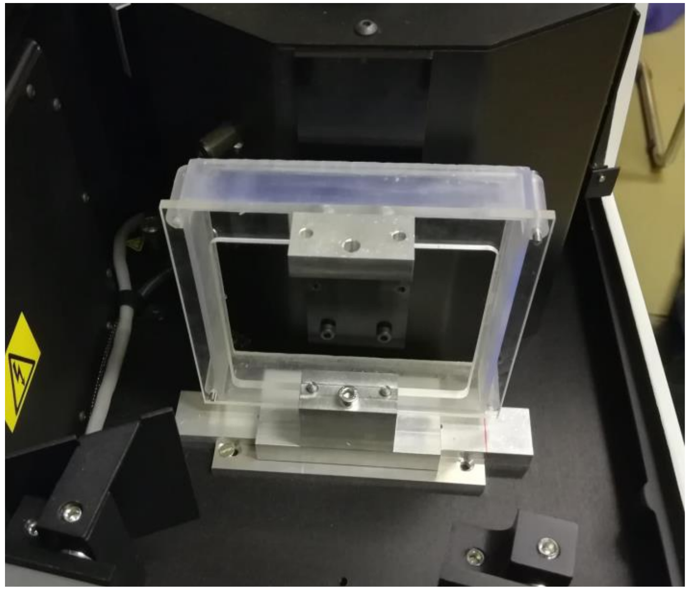


TOTAL TRANSMITTANCE

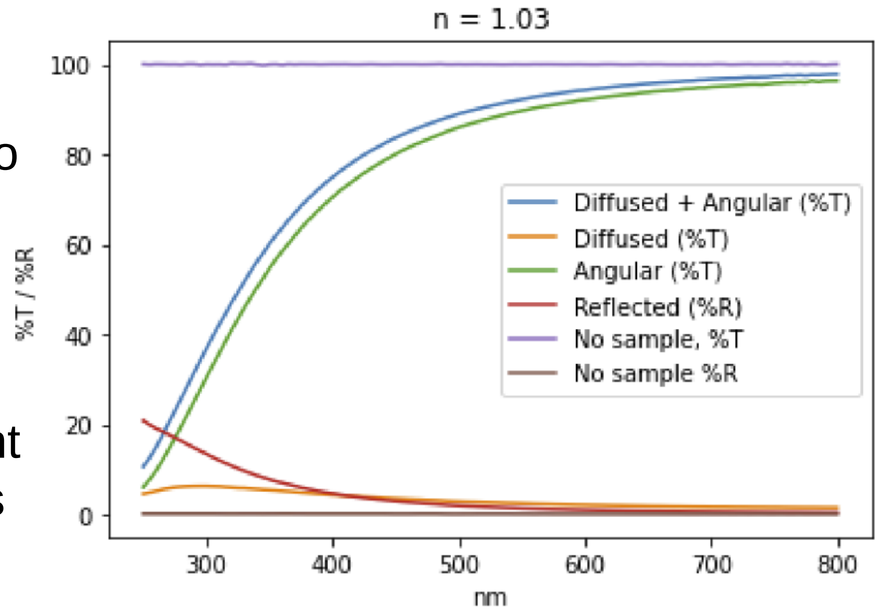


DIFFUSE TRANSMITTANCE

LINEAR TRANSMITTANCE
=
TOTAL T. – DIFFUSE T.

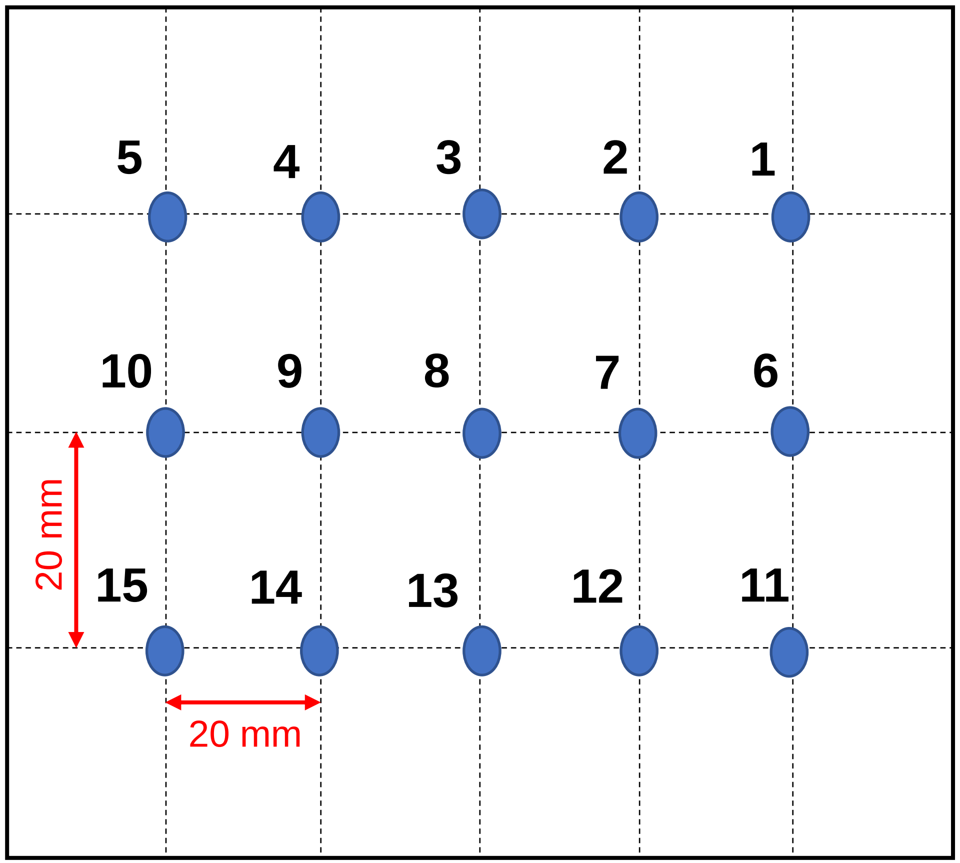


Each tile was placed into a holder (10x10 cm^2) and mounted onto a metal ridge sliding perpendicular to the beam to explore different positions of the samples



TILE LAYOUT

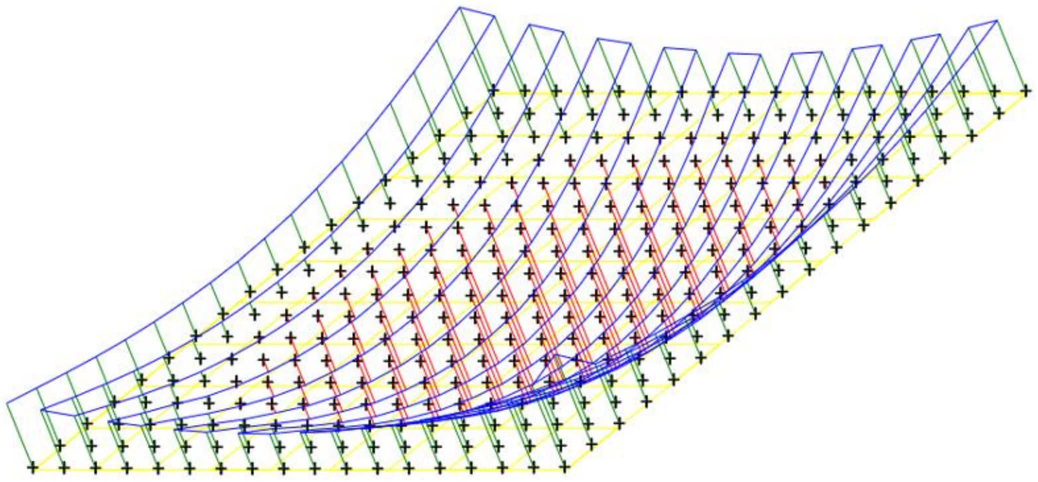
10x10 cm^2 Tile



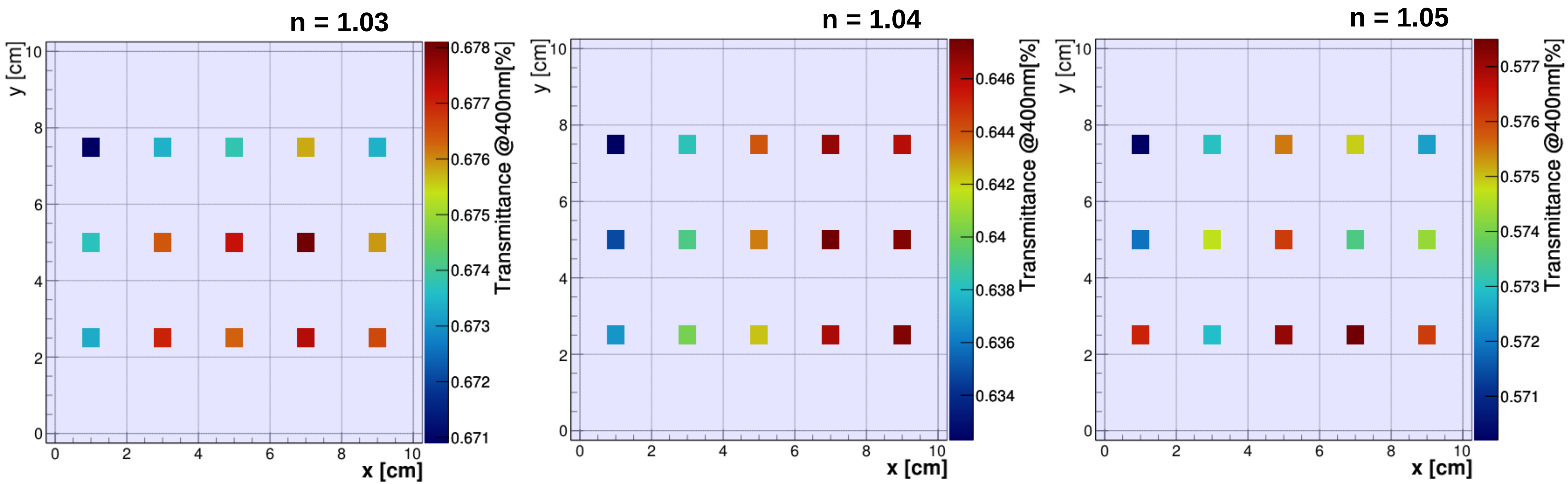
Transmittance measured at 15 different points on the tile

Tile thickness = 2 cm

Thickness not uniform because of the meniscus shape due to fabrication process



TRANSMITTANCE MEASUREMENTS



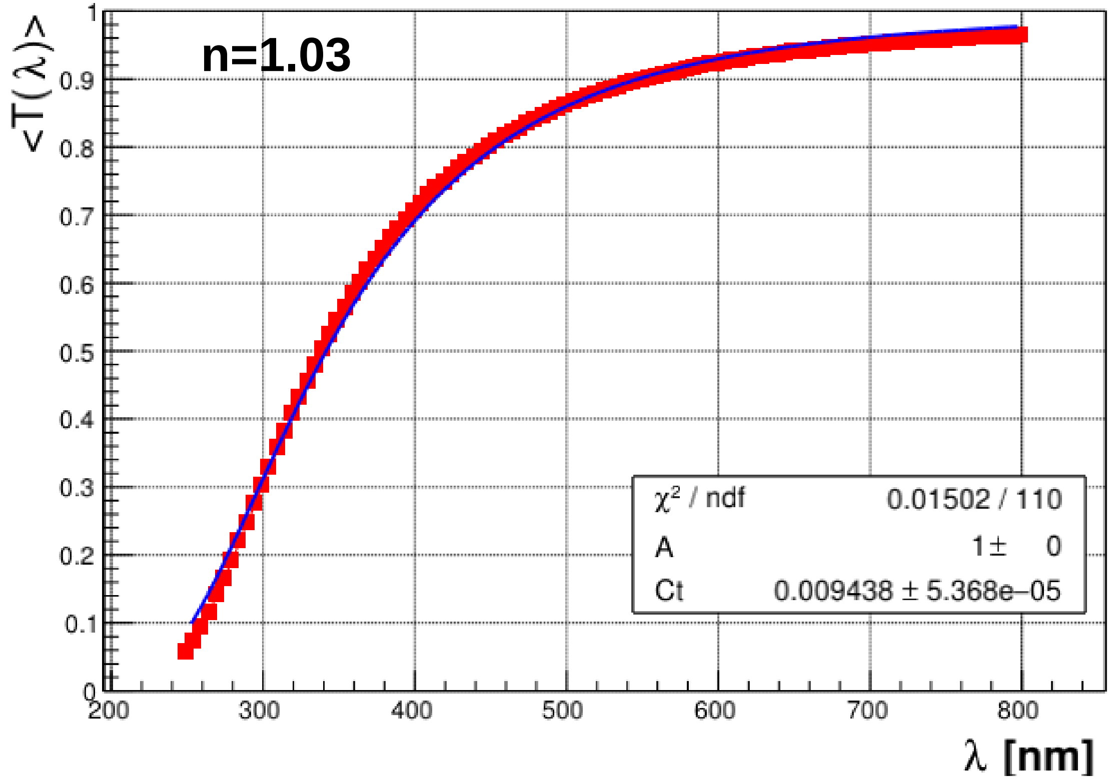
Small transmittance dispersion around 0.6%, which ensures a high uniformity

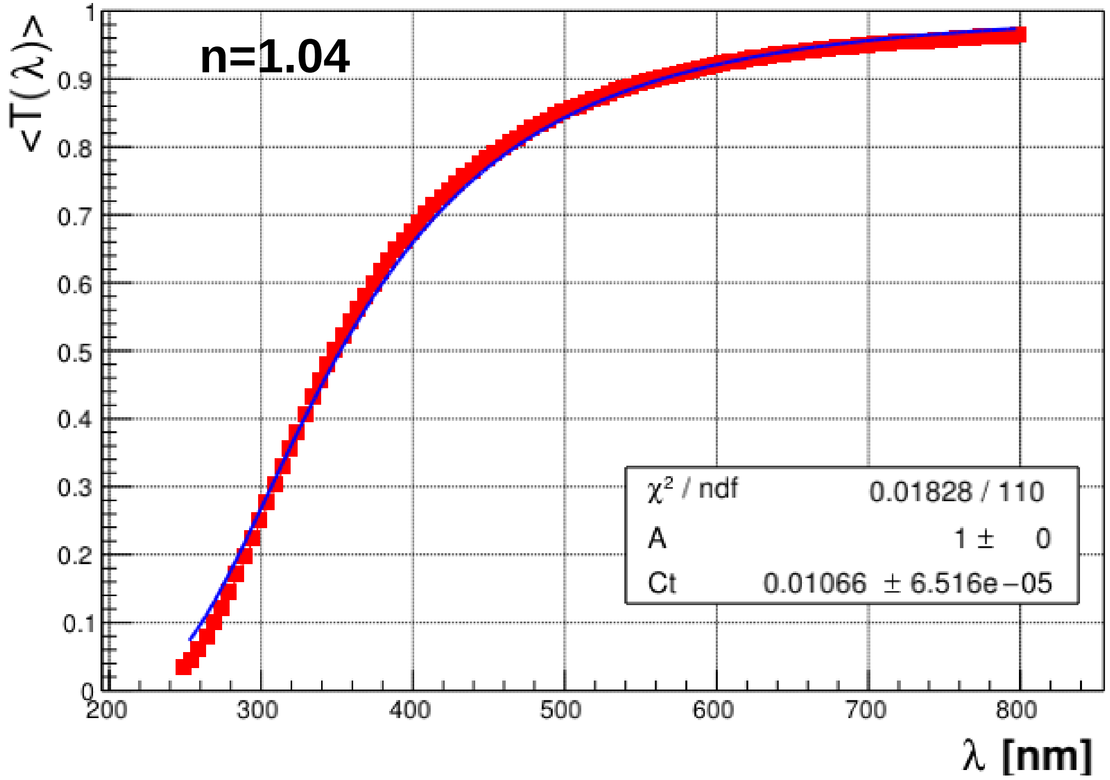
Maximum Transmittance region not localized in the center where tile is supposed to be thinner, **Minimum Transmittance on the borders** as expected

FIT TRANSMITTANCE (Tile n=1.03 – 1.04)

Transmittance fitted by **Hunt formula**:

$$T(\lambda) = e^{-\frac{t}{\Lambda_{trasm}}} = e^{-t\left(\frac{1}{\Lambda_A}+\frac{1}{\Lambda_S}\right)} = A \cdot e^{-\frac{C\,t}{\lambda^4}}$$





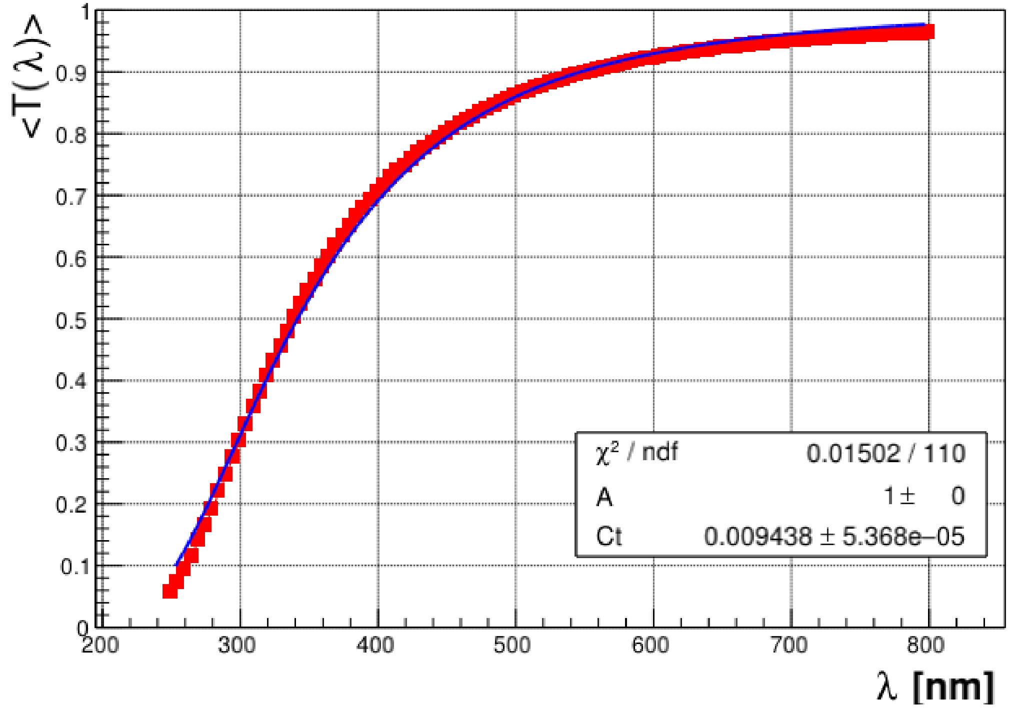
WHAT HAPPENS BY INCLUDING THE ABSORPTION CONTRIBUTION IN THE HUNT FORMULA?

FIT TRANSMITTANCE (Tile n = 1.03)

Transmittance fitted by **Hunt basic**:

$$T(\lambda) = e^{-\frac{t}{\Lambda_{trasm}}} = e^{-t\left(\frac{1}{\Lambda_A}+\frac{1}{\Lambda_S}\right)} = A \cdot e^{-\frac{C\,t}{\lambda^4}}$$

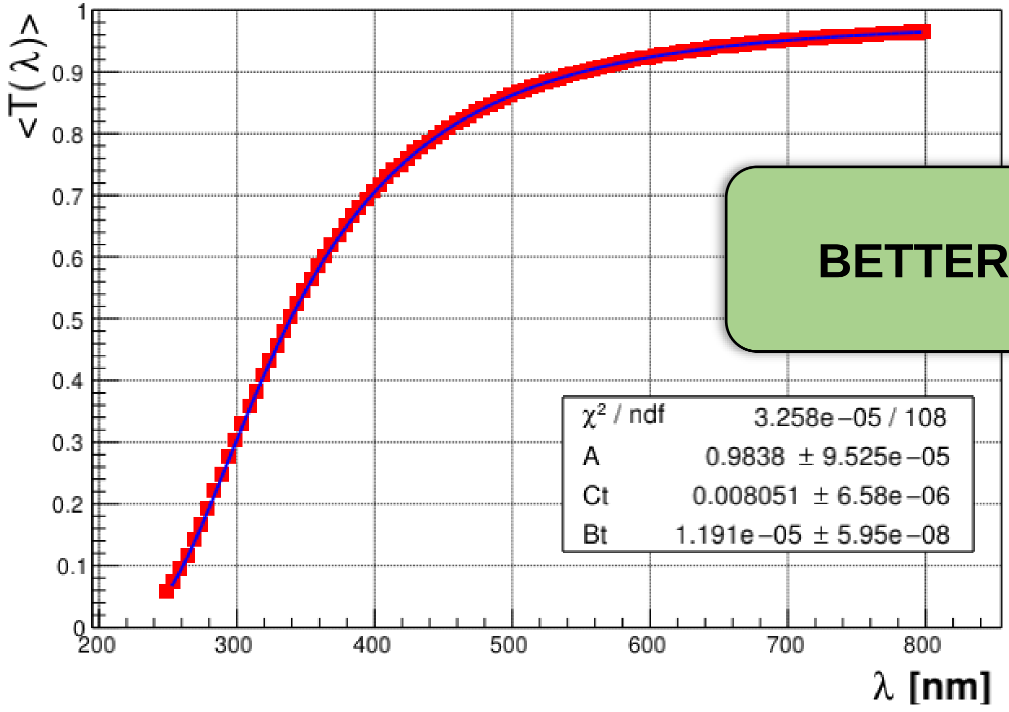
Assuming:
Λ_A ***negligible***
$\Lambda_S \sim \lambda^4$



Transmittance fitted by **Hunt extended**:

$$T(\lambda) = e^{-\frac{t}{\Lambda_{trasm}}} = e^{-t\left(\frac{1}{\Lambda_A}+\frac{1}{\Lambda_S}\right)} = A \cdot e^{-\frac{B\,t}{\lambda^8}} \cdot e^{-\frac{C\,t}{\lambda^4}}$$

Assuming:
$\Lambda_A \sim \lambda^8$
$\Lambda_S \sim \lambda^4$



BETTER FIT

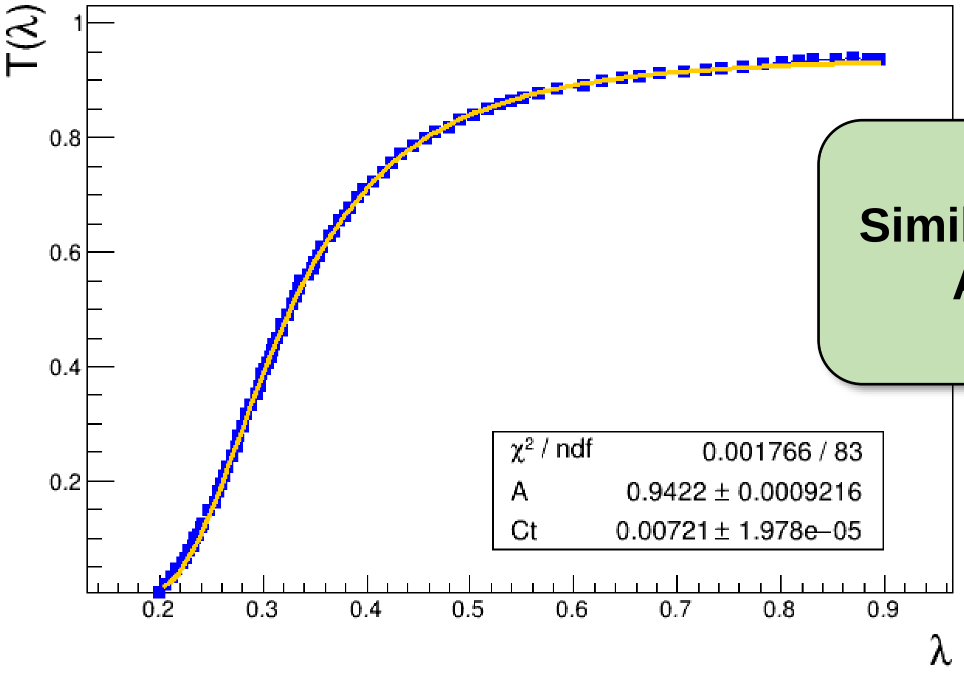
<T> average of the transmittance values at the different points on tile #1 (n = 1.03)

TESTING THE HUNT EXTENDED FORMULA ON A KNOWN DATASET

The Hunt extended formula was validate through a fit of the transmittance values from the dataset in *E Aschenauer at al*. **Optical characterization of n=1.03 silica aerogel used as radiator in the RICH of HERMES**

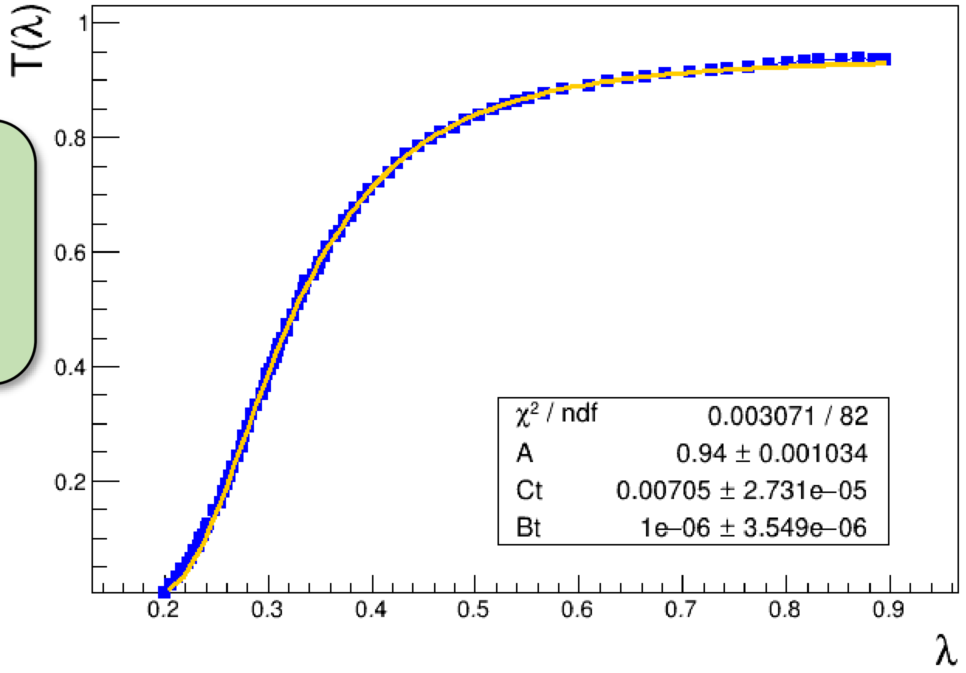
Transmittance fitted by **Hunt formula**:

$$T(\lambda) = e^{-\frac{t}{\Lambda_{trasm}}} = e^{-t\left(\frac{1}{\Lambda_A}+\frac{1}{\Lambda_S}\right)} = A \cdot e^{-\frac{C\,t}{\lambda^4}}$$



Transmittance fitted by **Hunt extended formula**:

$$T(\lambda) = e^{-\frac{t}{\Lambda_{trasm}}} = e^{-t\left(\frac{1}{\Lambda_A}+\frac{1}{\Lambda_S}\right)} = A \cdot e^{-\frac{B\,t}{\lambda^8}} \cdot e^{-\frac{C\,t}{\lambda^4}}$$

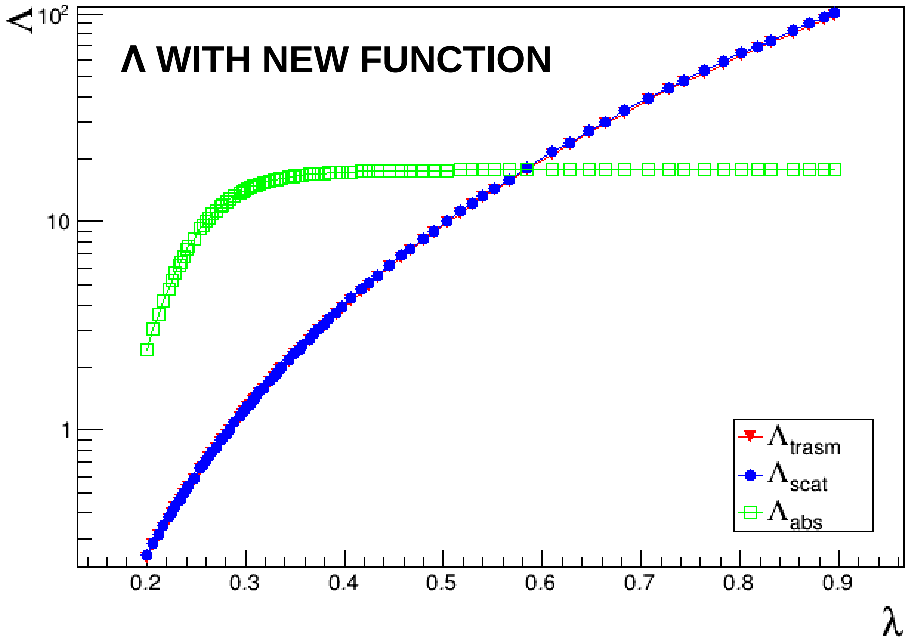


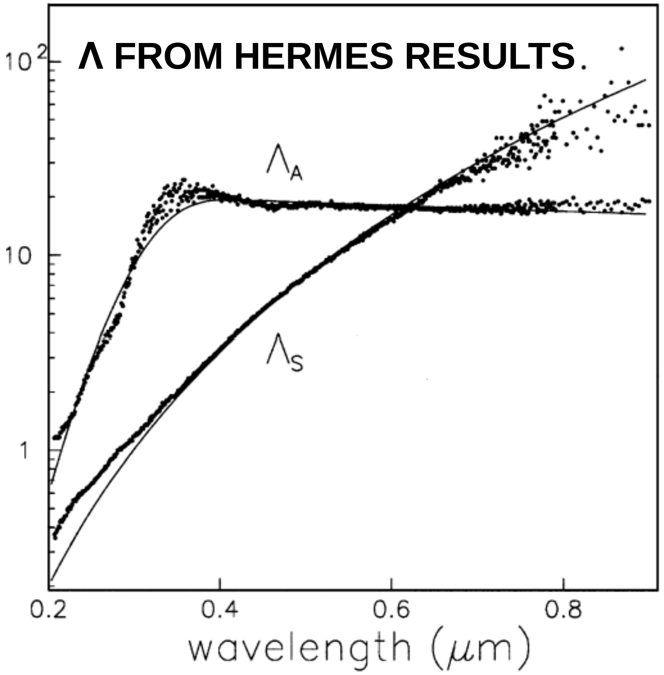
Similar values of A and Ct

TESTING THE HUNT EXTENDED FORMULA ON A KNOWN DATASET

Transmission, scattering and absorption lengths from the **Hunt extended function**:

$$\Lambda_{trasm} = -\frac{t}{\ln(T)} \qquad \Lambda_{scat} = \frac{\lambda^4}{C} \qquad \Lambda_{abs} = \frac{\lambda^8 \cdot t}{B\ t\ - \lambda^8 \cdot \ln(A)}$$





GOOD AGREEMENT BETWEEN THE RESULTS,
LET'S TRY THE FUNCTION ON OUR DATA

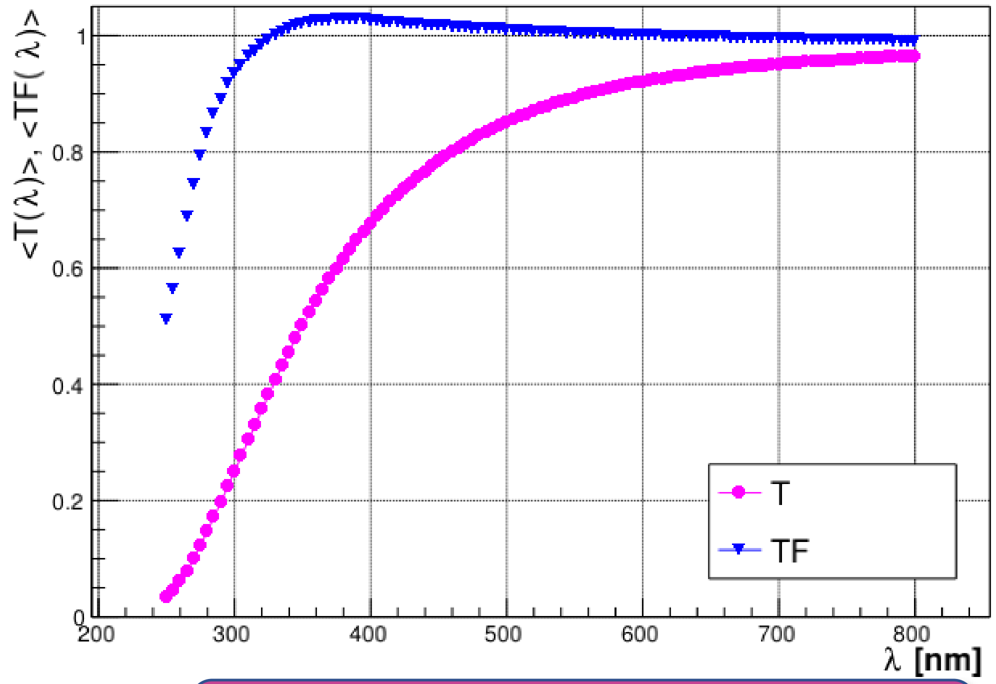
Data from: *E Aschenauer at al*. **Optical characterization of n=1.03 silica aerogel used as radiator in the RICH of HERMES**

TRANSMITTANCE AND TRANSFLECTANCE (Tile n = 1.03)

T and TF fitted by **Hunt formula**:

$$T(\lambda) = A \cdot e^{-\frac{C\,t}{\lambda^4}}$$

$$TF = T(\lambda) \cdot e^{\frac{C\,t}{\lambda^4}}$$



TF > 1 at 300 < λ < 400
(SOMETHING IS NOT WORKING FINE)

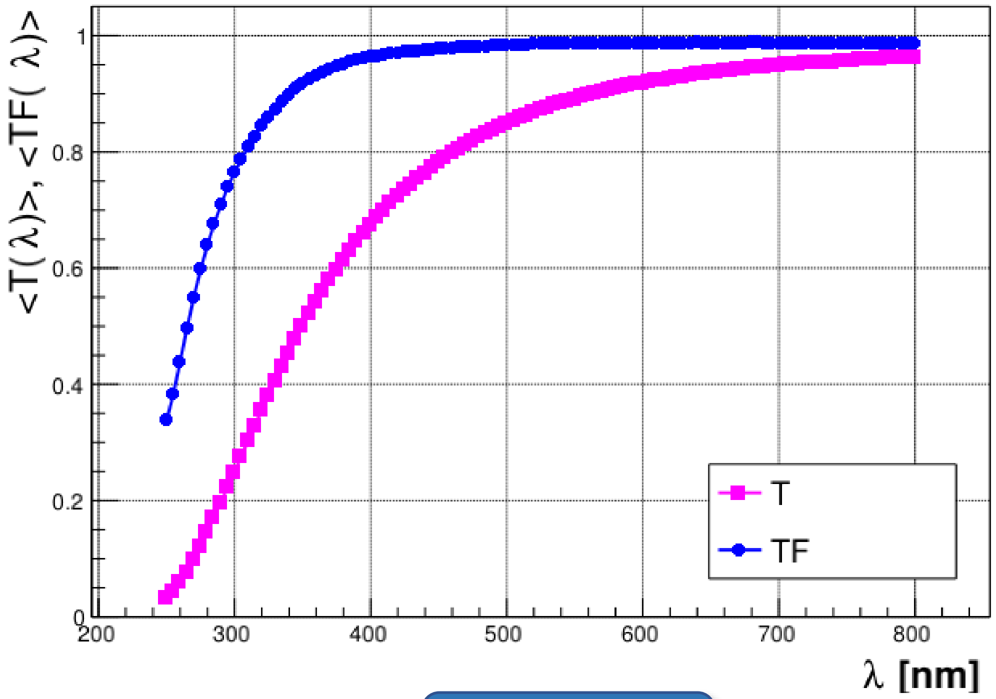
T and TF fitted by **Hunt extended**:

$$T(\lambda) = A \cdot e^{-\frac{B\,t}{\lambda^8}} \cdot e^{-\frac{C\,t}{\lambda^4}}$$

$$TF = T(\lambda) \cdot e^{\frac{C\,t}{\lambda^4}}$$

NOTE

Ct values are different because they come from different fit functions



TF < 1

TRANSMISSION LENGTH (Tile n=1.03)

$$T(\lambda) = e^{-\frac{t}{\Lambda_{trasm}}} = e^{-t\left(\frac{1}{\Lambda_A}+\frac{1}{\Lambda_S}\right)} = A \cdot e^{-\frac{B\,t}{\lambda^8}} \cdot e^{-\frac{C\,t}{\lambda^4}}$$

TRANSMISSION LENGTH:

$$T(\lambda) = e^{-\frac{t}{\Lambda_{trasm}}}$$

$$\Lambda_{trasm} = -\frac{t}{\ln(T)}$$

SCATTERING LENGTH:

$$e^{-\left(\frac{t}{\Lambda_S}\right)} = e^{-\frac{C\,t}{\lambda^4}}$$

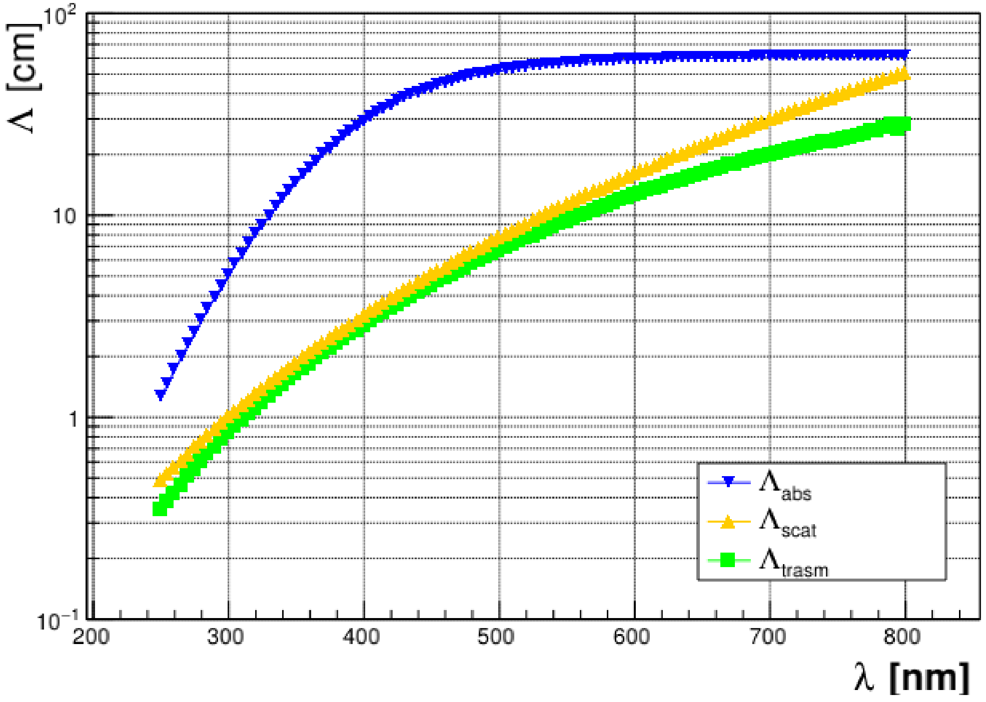
$$\Lambda_{scat} = \frac{\lambda^4}{C}$$

ABSORPTION LENGTH:

$$e^{-\left(\frac{t}{\Lambda_A}\right)} = A \cdot e^{-\frac{B\,t}{\lambda^8}}$$

$$\Lambda_{abs} = \frac{\lambda^8 \cdot t}{B\,t - \lambda^8 \cdot \ln(A)}$$

Lengths evaluated from average transmittance values.



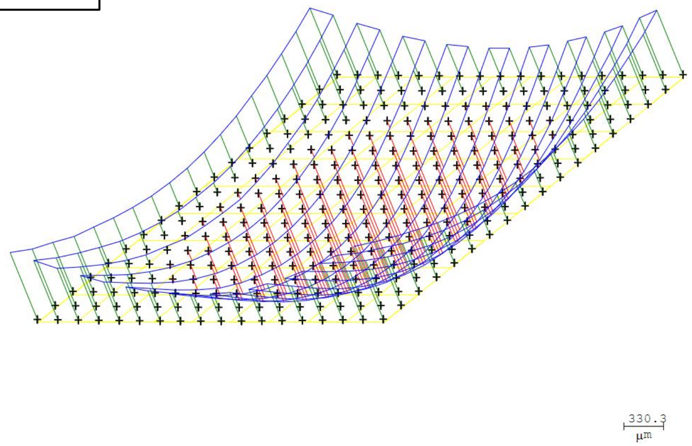
SMALL IMPACT OF THE ABSORPTION ON THE TRANSMISSION LENGTH

TOUCH PROBE

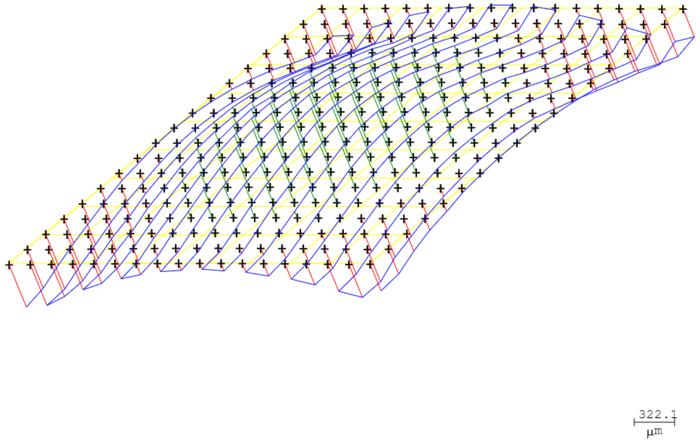
Minimum, maximum, average and std deviation of the measured thickness:

n = 1.03

Y -

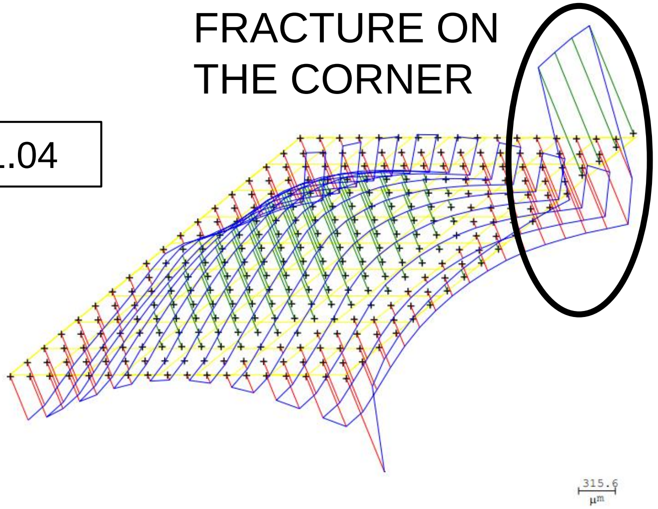


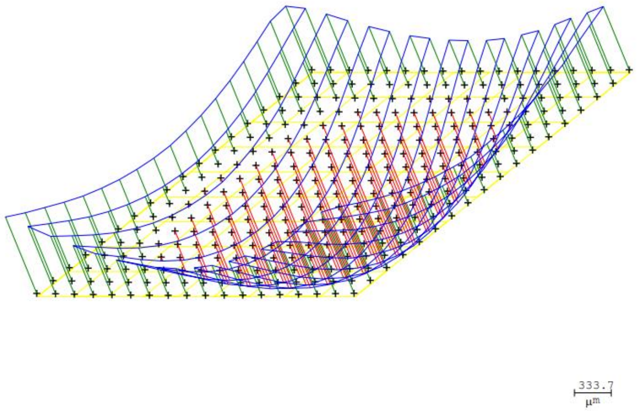
Y +



n = 1.04

FRACTURE ON THE CORNER





n=1.03
min tickness (mm): 19.690
max tickness (mm): 20.385
standard deviation: 0.172
average (mm): 19.955

n=1.04
min tickness (mm): 19.271
max tickness (mm): 21.798
standard deviation: 0.335
average (mm): 19.641

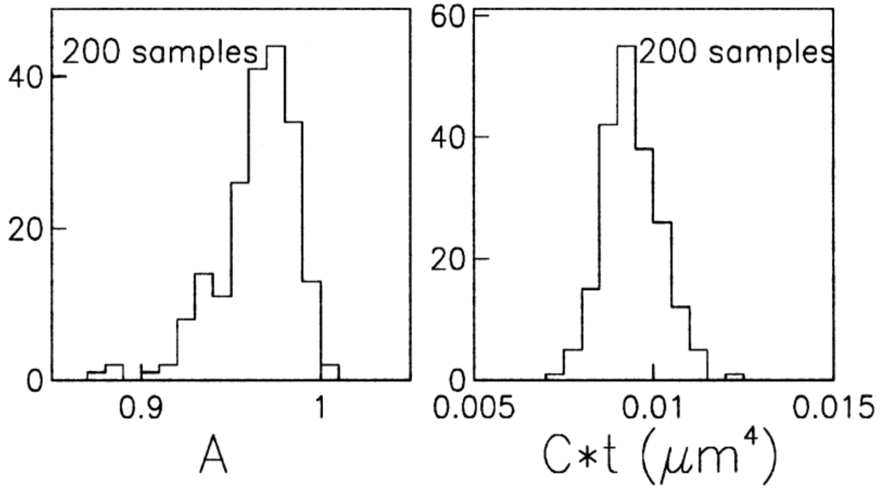
n=1.05
min tickness (mm): 19.965
max tickness (mm): 20.479
standard deviation: 0.098
average (mm): 20.106

MENISCUS SHAPE DUE TO FABRICATION PROCESS

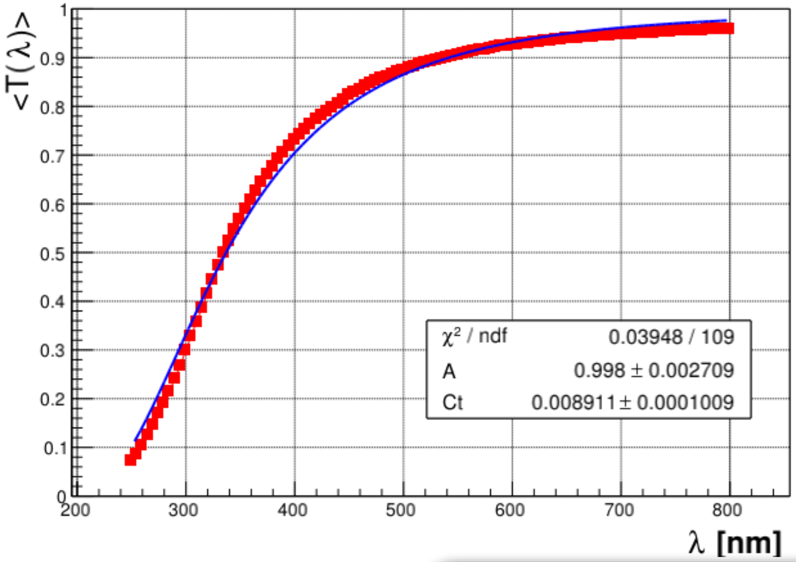
Tile 6-7: DEGRADATION IN TIME

Tiles 6 and 7 (t = 1 cm) were originally bought for the HERMES collaboration back in 2000.

They have been stored in air without particular care.
It is reasonable to think that they have undergone degradation.



A and Ct estimated as the average over 200 samples (tiles 6-7 were part of these samples)



Tile	2000		2022	
	A	Ct	A	Ct
6	0.964	0.0094	0.998 ± 0.003	0.0089 ±0.0001
7			1± 0	0.00682 ± .00084

Slight increase of absorption-related A and decrease of scattering-related Ct

Total transmittance used in calculations.
Low accuracy!
FURTHER ANALYSIS REQUIRED

OPTICAL PROPERTIES - SUMMARY

Results @ 400 nm

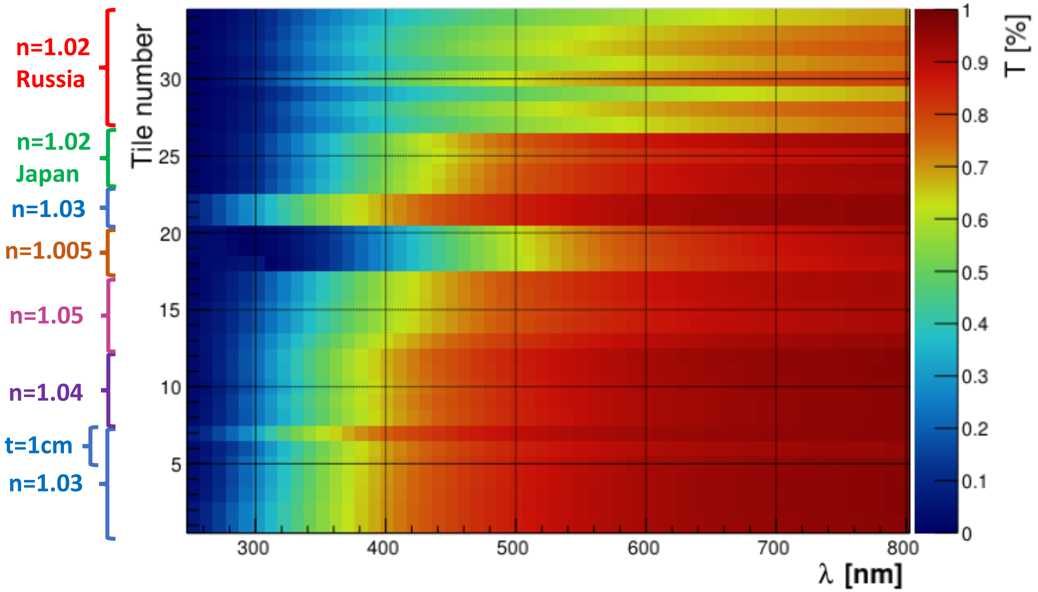
Tile	n	T_{meas} [%]	Λ_t [cm]	Λ_t datasheet	t_{avg} [cm]	Tile	n	T_{meas} [%]	Λ_t [cm]	Λ_t datasheet	t_{avg} [cm]
1		0,71	5,64	6,27	1,97	18		0,29	1,61		2,00
2		0,71	5,68	6,32	1,98	19	1,005	0,29	1,65		2,06
3		0,70	5,64	6,13	1,99	20		0,29	1,69		2,06
4	1,03	0,70	5,54	6,06	1,98	21	1,03	0,69	5,40		2,02
5		0,70	5,47	6,00	1,97	22		0,69	5,59		2,03
6		0,69	2,65		0,98	23		0,54	3,24		2,00
7		0,75	3,47		0,97	24	1.02	0,53	3,10		2,00
8		0,66	4,73	5,47	1,94	25		0,52	3,04		2,00
9		0,67	4,92	5,61	1,95	26		0,53	3,13		2,00
10	1,04	0,66	4,78	5,58	1,96	27		0,38	2,09		2,00
11		0,67	4,96	5,71	1,97	28		0,42	2,32		2,00
12		0,68	5,00	5,86	1,96	29		0,34	1,85		2,00
13		0,63	4,41	3,59	2,02	30	1.02	0,45	2,56		2,00
14		0,58	3,73	3,54	2,01	31		0,38	2,09		2,00
15	1,05	0,58	3,73	3,45	2,02	32		0,42	2,31		2,00
16		0,57	3,59	3,79	2,00	33		0,40	2,19		2,00
17		0,57	3,60	3,86	1,98	34		0,36	1,94		2,00

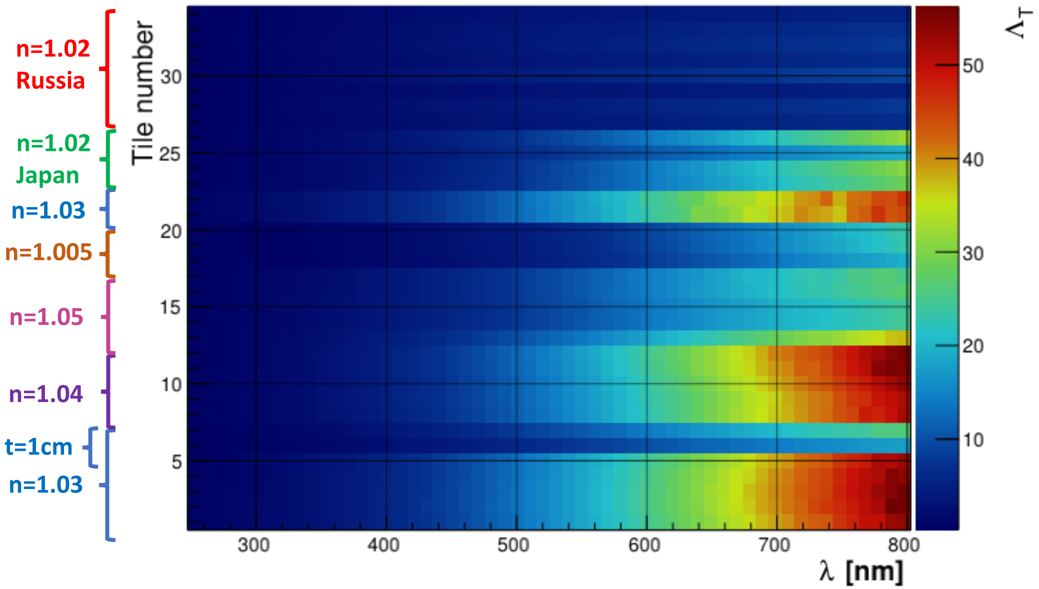
Estimated Λ_t @400nm lower than datasheet values

FURTHER INVESTIGATION REQUIRED

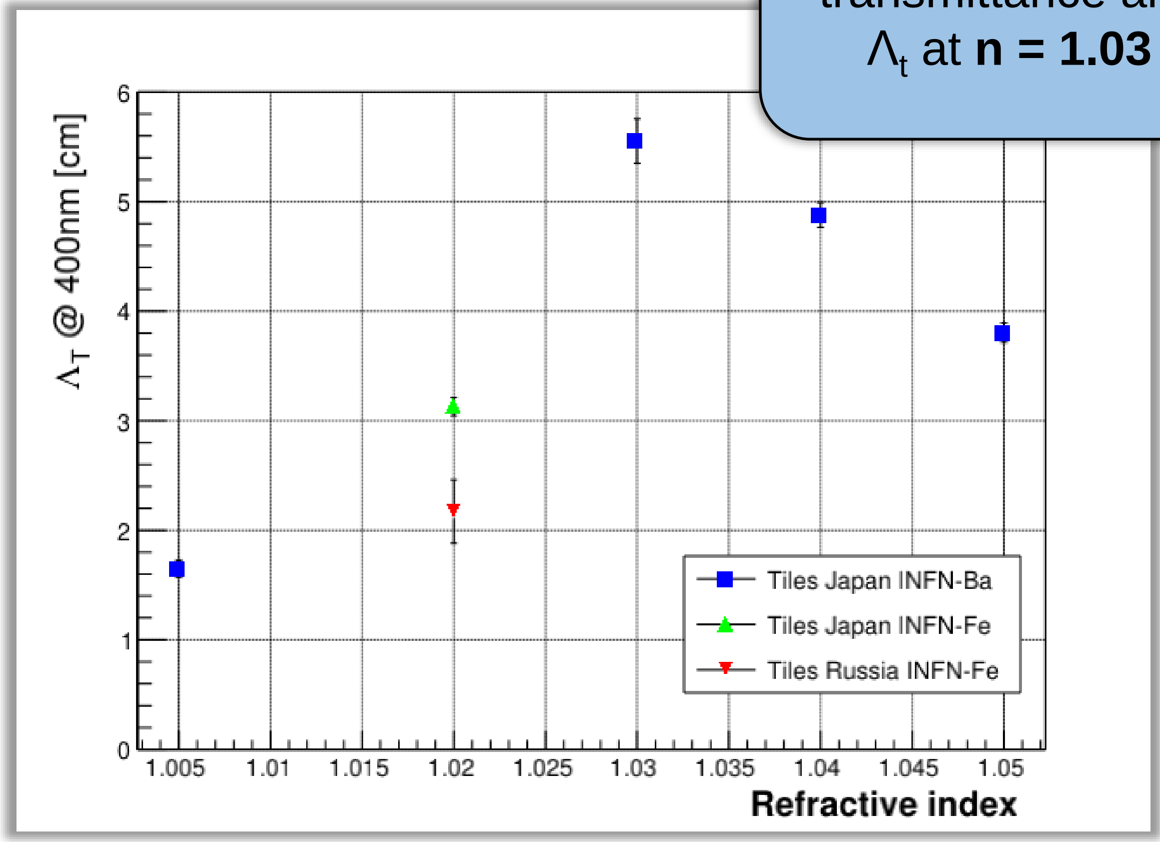
MIGHT BE OVERESTIMATED BECAUSE
ONLY TOTAL TRANSMITTANCE AVAILABLE

OPTICAL PROPERTIES - SUMMARY





MAXIMUM transmittance and Λ_t at **n = 1.03**



CONCLUSION

- 22 silica aerogel tiles characterized in terms of transmittance
  - **Small transmittance dispersion** among the sampling points on the tiles
- Data fitted by a 3-parameters Hunt extended formula
- Transmission, absorption and scattering lengths extracted from transmittance measurements
  - **Absorbance negligible** with respect to the transmission length
- Maximum and minimum thickness value per tile estimated from transmittance data
  - **Not uniform thickness** on the tile due to meniscus shape
- **Maximum transmittance** and transmission length observed for tiles with **n = 1.03**

WHAT'S NEXT?

- Further investigation on transmission length discrepancy between estimated and datasheet values
- Performing more in-depth measurements of the Tile 6 and 7 to investigate their degradation in time
- Improvement of accuracy including measured thickness in the transmittance measurements on tiles with n = 1.02